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ABSTRACT

This master's thesis reports results of a study that: (1) developed, used, and validated a classification instrument of Piagetian developmental levels of high school science students (N=16); (2) determined the effects of traditional and Piagetian-based instruction of two formal topics, the mole concept and atomic theory, on students not classified by development level; and (3) determined the effects of traditional and Piagetian-based instruction on the topic of atomic theory on the achievement of students at three different Piagetian developmental levels as determined by the instrument. Findings validate the classification instrument, support Piagetian-based instruction as a more effective method of instruction for both atomic theory and mole concepts, and support both methods of instruction for formal operational students in presenting atomic theory concepts. (CS)

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THE EFFECTS OF TWO METHODS OF TEACHING ABSTRACT TOPICS IN HIGH SCHOOL CHEMISTRY

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A Thesis

Presented to

The Faculty of the Department of Education

Sam Houston State University

BEST COPY AVAILABLE

In Partial Fulfillment

of the Requirements for the Degree of

Master of Arts

by

Nellie E. Kletzly

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THE EFFECT OF TWO METHODS OF TEACHING ABSTRACT

TOPICS IN HIGH SCHOOL CHEMISTRY

by

Nellie E. Kletzly

A THESIS

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Purpose

The purposes of this investigation were to determine the following: (1) to develop, use and validate a classification instrument of Piagetian developmental levels of students enrolled in selected high school science courses; (2) to determine the effects of traditional and Piagetian-based instruction of two formal topics, the mole concept and atomic theory on students not classified by development level; and, (3) to determine the effects of traditional and Piagetian-based instruction of one of the topics, atomic theory, on the achievement of students at three different Piagetian developmental levels as determined by the instrument.

Methods

The methods used to obtain data for this study were: (1) testing the treatment group with the classification instrument and the experimental sample with another accepted instrument, (2) administering a diagnostic math test (3) providing Piagetian-based instruction for the experimental sample and traditional instruction for the control sample on the abstract topics of atomic theory and the mole concept, (4) determining the validity of the Piagetian developmental level classification of the experimental sample by the chi square method; (5)

determining the effect of math background and the effects of the two methods of instruction by the computer analysis of covariance; and, (6) determining the effects of the two methods of instruction on students at three different Piagetian developmental levels during the atomic theory phase of the experiment by t-test analysis.

Findings

1. The Piagetian developmental level classification was valid using the investigator's instrument.

2. Piagetian-based instruction was more effective than traditional instruction during both the atomic theory and the mole concept phases of the experiment.

3. Piagetian-based instruction was more effective for transitional level students during the atomic theory phase of the experiment.

4. Both methods of instruction were effective for formal operational students during the atomic theory phase of the experiment.

David L. Henderson

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In Memoriam to Mr. Harmon C. Agnew, whose cooperation in administering the inventory and implementing some of the instructional techniques is appreciated.

To Ms. Toni Baker- Physics I and II teacher at Humble High School, who helped with equipment and cooperated willingly in implementing some of the instructional designs.

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To Dr. Anton E. Lawson, Associate Professor of Science Education, Arizona State University, Tempe, Arizona for his comments and invaluable materials which made a major part of this thesis possible.

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INTRODUCTION

Chapter 1

This study began as a search for a practical and effective method for teaching formal or abstract topics in high school chemistry. A survey of the literature indicated that a major reason students have difficulty with formal topics is that such topics require a type of reasoning, called formal operational by Jean Piaget, that many students do not have. It was assumed that if formal topics were taught through an instructional method that allows students to operate on a concrete operational level, then both concrete and formal operational students would learn formal topics better.

To test the assumption, an experimental study was carried out. In the course of the study the researcher developed an instrument used in classifying the students according to developmental levels. The Piagetian-based instructional methods used in the study were also developed by the researcher from a consideration of a variety of methods suggested in the literature.

Statement of the Problem

Specifically, the purposes of this study were:
(1) to develop, use, and validate a classification instrument of Piagetian developmental levels of students enrolled in selected high school science courses; (2) to determine the effects of traditional and Piagetian-based instruction of two formal topics, the mole concept and atomic theory on student achievement; and, (3) to determine the

effects of traditional and Piagetian-based instruction of one of the topics, atomic theory, on the achievement of students at three different Piagetian developmental levels as determined by the instrument.

The selection of atomic theory and the mole as the formal topics in this study was based on Herron's taxonomy of chemical concepts.[1] Herron defines formal concepts as:[2] "Concepts that have imperceptible examples, imperceptible attributes, or both..." The validity of the Piagetian level classification instrument was determined by the use of other accepted classification instruments.

Hypotheses

The hypotheses tested in this study, stated in null form, were:

1. There would be no significant difference in the Piagetian level classification of students when tested with the researcher's instrument and other accepted instruments.

2. During the mole concept phase of the research, no significant difference in the achievement scores of the traditionally instructed control sample and an experimental sample which had received Piagetian-based instruction would be found.

3. During the atomic theory phase of the research, no significant difference in the achievement scores of the traditionally instructed control sample and an experimental sample which had received Piagetian-based instruction would be found.

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[1] J. D. Herron, Science Education, LXI (2) 185 (1977).

[2] J. Dudley Herron, "Piaget in the Classroom", Journal of Chemical Education, LV (March, 1978) p. 169.

4. There would be no significant difference in achievement on atomic theory of concrete operational students in the control and experimental samples.

5. There would be no significant difference in achievement on atomic theory of transitional operational students in the control and experimental samples.

6. There would be no significant difference in achievement on atomic theory of formal operational students in the control and experimental samples.

Delimitation of the Problem

All subjects were administered the researcher's Piagetian developmental level test on September 13, 1979 with the exception of two who were tested upon enrollment between January 19-23, 1980 and February 4-8, 1980 respectively. Both a range and combinatorial (grouped without to the order of arrangement within the group)[3] response key was developed before the administration of the investigator's inventory for categorization purposes. The tasks selected for the investigator's inventory were: Conservation of solid amount, liquid amount using cylinders, elimination of contradiction, reciprocal implications, separation of variables, and deductive reasoning skills. These tasks were the ones used most extensively on Lawson's test,[4] Longeot's test,[5]

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[3] G. & C. Merriam, eds., Webster's New Collegiate Dictionary, (Springfield, MR: G. & C. Merriam, 1951).

[4] Anton E. Lawson, "Classroom Test of Formal Operations", Journal of Research in Science Teaching, XV(1), 11-24, 1978.

[5] Donald J. Sheehan, trans., "The Effectiveness of Concrete and Formal Instructional Procedures with Concrete and Formal Operational Students", (EdD dissertation, State University of New York, Albany, 1975), test copy.

and An Inventory of Piaget's Developmental Tasks[6], which were used later in the study to obtain evidence of the instrument's construct and convergent validity. Construct validity is defined as: "the extent to which measurements support the existence of an hypothesized trait or ability". Convergent validity is defined as: "the extent to which two or more sets of measurements are highly correlated and thus measure the same trait, used to obtain evidence regarding construct validity"[7]. The investigator-developed instrument was submitted to Dr. Anton E. Lawson, a noted authority on Piagetian-type test development and validation, for his critique and analysis. There was serious doubt of its reliability, validity, and usefulness. The three primarily cited instruments were used to retest and reclassify, if necessary, the students in the experimental sample of the treatment group as to their Piagetian developmental level during the atomic theory phase of the research from October 22, 1979 to November 5, 1979. Only the Longeot test was used during the mole concept phase of the research from February 5-19, 1980 for an additional class of experimental subjects. The Longeot test was used because of its ease of administration, time limitations, and fewer problems in scoring responses.

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[6]Center for Research in Thinking and Language, Department of Psychology, Catholic University, An Inventory of Piaget's Developmental Tasks, (Washington, D. C.: Hans Furth, 1970), pp. 1-48.

[7]Gilbert Sax, Principles of Educational Measurement and Evaluation, (Belmont, CA: Wadsworth, 1974), p.593.

During the atomic theory phase of the experiment, one class of 16 first year chemistry students was selected as the experimental sample. Two classes of 23 and 22 each were used as the control sample. During the mole concept phase of the experiment, two classes of 20 and 18 students each were used as the control sample. Two classes of 16 and 19 students each were choser as the experimental sample. In both phases of the treatment, the control sample received traditional instruction and the experimental sample received Piagetian-based instruction.

For the past ten years, a locally developed math diagnostic test had been administered to all first year chemistry and physics students. The relationship between the math ability, as determined by this test, and the criterion measure scores was calculated with Western Michigan University's analysis of covariance technique using Sam Houston State University's Digital Equipment System-20 computer system STP program.

During the atomic theory phase of instruction, an additional consideration was that two of the experimental subjects and three of the control subjects were concurrently enrolled in first year physics where atomic theory was incidentally referred to both before and during the treatment and it was assumed that would lead to criterion contamination. During the mole concept phase of the instruction, three subjects in each of the samples were enrolled in Physics I. The analysis of covariance should have controlled for some criterion contamination except for history and maturation interactions from the September 10th, 1979 math testing date to the criterion measure testing date of February 19th, 1980.

Basic Assumptions

It was assumed that the Piagetian developmental level of the students would affect the level of achievement on formal concepts.[8] Course grades would not necessarily be reflective of student development for several reasons widely reported in chemical education literature but not relevant in this study because the data were not collected, used, nor controlled.[9] Instructional time lost for various reasons could be replaced in subsequent class meeting in both the control and experimental samples of the treatment group. It was assumed that the assignment of Piagetian levels were valid for both the control and experimental samples of the treatment group; the experimental sample was retested but the control sample was not. It was further assumed that sufficiently different instructional procedures could be developed and used with both samples such that the differences in their effects would be discernable and measurable.[10]

Definition of Terms

All the definitions are quoted verbatim from Piaget: A Dictionary of Terms by Antonio M. Battro with a preface by Jean Piaget, translated

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[8] Ron Good, Kromhou[illegible]bert A., and Mellon, E. K., "Piaget's Work and Chemical Education", [illegible]urnal of Chemical Education, LVI(7), p. 426, 1979.

[9] Good, op. cit., p. 428; Harvey Williams and others, "Formal Operational Reasoning by Chemistry Students", Journal of Chemical Education, LVI(9), pp. 599-600, 1979.

[10] R. M. Gagne and Briggs, L. J., Principles of Instructional Design, (San Francisco, CA: Holt, Reinhart and Winston, 1974), Barry J. Wadsworth, Piaget for the Classroom Teacher, (New York: Longman, 1978), pp. 161-179.

from the French and edited by Elizabeth Rutschi-Hermann, Dr. Iur, and Sarah F. Campbell, Ph. D.[11] The definitions in quotation marks are translations of Piaget's written words and were not subjected to interpretive comment, which, since it is subjective, would open the terms to the possibility of re-interpretation or misinterpretation, particularly in view of Piaget's highly abstract patterns of thought.

> Operations, concrete--"The operations of the first degree to which belong the formal operations are themselves concrete operations." (concrete manipulation of objects).
>
> Operations, formal or hypothetico-deductive--The formal operations ". . .constitute exclusively the structure of final equilibrium, toward which tend the concrete operations, when they are reflected in more general systems combining the propositions they express." ". . .formal or hypothetico-deductive operations. Now, those formal operations are, in their structure, nothing but concrete operations, but transposed into terms of propositions, i.e., integrating concrete classes and relations into a system of implications and of incompatibilities expressed by propositions."[12]
>
> Stage--The stages are the sections in the genetic evolution which satisfy the following conditions: (1) It is necessary that the order of the various acquisitions be constant. (For example: the acquisition of the notion of volume is always after that of the notion of weight.)
> (2) Each stage is characterized by a structure and not by a single juxtaposition of properties.
> (3) The structure constructed at a given age becomes a part of the structures of the age following. (Integration of the inferior structures into superior ones.)
> (4) In each stage we distinguish a moment of preparation and a moment of accomplishment.

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[11] Antonio M. Battro, Trans. ed., Elizabeth Rutschi-Hermann and Campbell, Sarah F., Piaget: A Dictionary of Terms. (New York: Pergamon Press, Inc., 1973).

[12] Ibid., pp. 123-124.

(5) We ought to distinguish the process of creation and the final forms of equilibrium (always relative). "The stages are to be understood as the successive phases of the regular processes, which are reproduced like rhythms, on the superimposed levels of behavior and consciousness."

Chapter 2

LITERATURE REVIEW

This chapter consists of a review of the literature about: (1) general references, (2) impact on science education, (3) the nature of formal reasoning, (4) tests, and (5) instructional techniques.

General References

Most of Piaget's work is published in French so the search began with Flavell's translation.[1] This book is relative-y free of the translator's interpretive comment and is a good fundamental resource. Piaget has endorsed it as the most authoritative translation in English up to 1963.

By contrast, Rotmăn's book[2] contains many inferences and critical interpretations of Piaget's work over the last fifty years. The excellent exposition is clear without being simplistic especially on the theory of evolution, self-regulation, and logicomathematical knowledge. Rotman's main objections seem to be about Piaget's disregard of the place of language in his theory of cognition. These criticisms are similar to those of the linguist Noah Chomsky. Gardner compares Chomsky's viewpoint that the underlying structures of the brain are governed by the universal grammar to that of Piaget who states that they are governed by the mental operations of which the human intellect is capable. Gardner concludes, however, that both Chomsky and Piaget

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[1] J. H. Flavell, The Developmental Psychology of Jean Piaget. (New York: Van Nostrand, 1963).

[2] Brian Rotman, Jean Piaget: Psychologist of the Real. (Ithaca, New York: Cornell University Press, 1977.

are concerned with the study of logical models of the human mind.[3] Chomsky's and Rotman's positions are very similar so the same logic can be used to counter Rotman's objections.

Gonzalves[4] developed an expanded analysis of the developmental theories of Piaget which is detailed but involves some interpretations. In Piaget: A Dictionary of Terms[5] a comparison allowed a more narrow viewpoint that seems closer to Piaget's own.

The Pascual-Leone model has been used to clarify Piaget's theory related to the thinking of 13 and 15 year old high school students. It was used by de Ribaupierre in finding the formal and logical constructs that accounted for individual differences among 15 year olds.[6] Some other attempts to use Piaget's cognitive developmental theories have not been useful, possibly because they were used to measure solutions, not decisions about how to solve problems.[7]

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[3]Howard Gardner, "Encounter at Royaumont", Psychology Today, XIII(2), pp. 14-16, 1979.

[4]Linda J. Gonzalves, "An Expanded Analysis of the Developmental Theories of Jean Piaget", (PhD dissertation, Rutgers University, 1978). Microfilm from University Microfilms, Dissertation Abstracts International, Ann Arbor, MI.

[5]Antonio M. Battro, trans. ed. Elizabeth Rutschi-Hermann and Campbell, Sarah F., Piaget: A Dictionary of Terms. (New York: Pergamon Press, Inc., 1973).

[6]Anik de Ribaupierre, "Mental Space and Formal Operations", (PhD dissertation, University of Toronto, 1978)., Microfilm from University Microfilms, Dissertation Abstracts International, Ann Arbor, MI.

[7]Robert J. Sternberg, "Stalking the IQ Quark". Psychology Today, XIII(4), pp. 42-54, 1979.

Impact on Science Education

Most studies on training on classification, seriation or conservation indicate that training is helpful in the short term, but it is doubtful that it helps later.[8] The student's mental development and background are more important than training acquired in innovative chemistry courses in successful course completion or in further studies.[9] There seems to be little "transfer" of training on designing controlled experiments to tasks involving different forms of formal reasoning.[10] The more advanced the student was in correlative reasoning ability, the more likely advancement in reasoning would occur.[11]

At the concrete level of development, students do not seem to understand abstract concepts, for example, constancy of mass and volume ratios in representing compounds as particles made up of atoms combined in definite proportions, phase changes of pure substances, atomic weight as the ratio of the mass of one atom to carbon-12, or the Arrhenius,

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[8] Ron Good, Kromhout, Robert A., and Mellon, E. K., "Piaget's Work and Chemical Education", Journal of Chemical Education, LVI(7) (1979), pp. 429-430.

[9] Miles Pickering, "The High Risk Freshman Chemist Revisited", Journal of Chemical Education, LIV(7) (1977) pp. 433-4.

[10] Anton E. Lawson and Wollman, W. T., "Encouraging the Transition from Concrete to Formal Cognitive Functioning-An Experiment", Journal of Research in Science Teaching, XIII, pp. 413-30, Summer, 1976.

[11] Albert L. Nous and Raven, Ronald, "The Effect of a Structured Learning Sequence on Children's Correlative Thinking about Biological Phenomena", Journal of Research in Science Teaching, X, pp. 251-262, 1973.

Bronsted-Lowry, or Lewis Acid Theories, even when models are used.[12] Good, Kromhout, and Mellon suggest that secondary science courses such as CHEM Study and Chemical Bond Approach (CBA) have been too abstract for most students.[13] Kolodiy questions whether outmoded educational practices during the high school years actually cause a regression in the thought level.[14]

Nature of Formal Reasoning

Proportionality is a formal concept that is required in many chemistry and physics problems and is the subject of much of the literature surveyed. Piaget's definition of "hypothetico-deductive" thought includes the use of the logic operations of disjunction, conjunction, implication, and equivalence to generate a set of 16 binary operations. This propositional thought can be used to generate hypotheses.[15] A much higher percentage of suburban secondary school

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[12] Good, Kromhout, and Mellon, op. cit., p. 428.

[13] Ibid.

[14] G. Kolodiy, "Piagetian Theory and College Science Teaching", Journal of College Science Teaching, IV, p. 261, 1974.

[15] William W. Bart, "A Comparison of Premise Types in Hypothetico-Deductive Thinking at the Stage of Formal Operations", Journal of Psychology, OXXXI(1), pp. 45-51, 1972.

students used proportional reasoning when compared to urban students.[16] Although it concerns younger students than those in this study, an excellent critique and explanation of Piaget's propositional logic was done by Ennis.[17] Keating has also treated propositional logic and extended it to other logical operations for bright children, some of whom were younger than the subjects of this paper.[18]

During the mole concept instruction, questions were formulated and used in small group and laboratory instruction based on the expected mathematics competencies reported in Renner and Paske's article. Those competencies which were based on higher desired student outcomes than those which had been taught to less than half the students in this study were omitted.[19] To evaluate student performances during the mole concept experiments in both the control and experimental samples of the treatment group, most of the hierachies referred to in Benefield and Capie's article were used at least once.[20] In the experimental situation involved in this study, (both the atomic theory and mole concept phases of instruction), isolation of variables was

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[16]Robert Karplus and Peterson, R., "Intellectual Development Beyond Elementary School II: Ratio: A Survey", Secondary School Mathematics, LXX, p. 813, 1970.

[17]Robert H. Ennis, "Children's Ability to Handle Piaget's Propositional Logic: Conceptual Critique", Review of Educational Research, VL, pp. 1-41, Winter, 1975.

[18]Daniel P. Keating, "Precocious Cognitive Development at the Level of Formal Operations", Child Development, XVII, pp. 276-280, March, 1975.

[19]John W. Renner and Paske, W., "Quantative Competencies of College Students", Journal of College Science Teaching, VI, p. 283, 1977.

[20]K. Elaine Benefield and Capie, William, "An Empirical Derivation of Hierachies of Proposition Related to Ten of Piaget's Sixteen Binary Operations", Journal of Research in Science Teaching, XIII, pp. 193-204, May, 1976.

based on Kuhn and Brannock's work.[21]

Instruments and Procedures for Assessing Piagetian Developmental Levels

The development of an acceptable instrument or procedure for measuring Piagetian developmental levels was one of the tasks to be accomplished during this study. Most of the published techniques were not suitable. Therefore, six of the sixteen competencies listed in "Piaget for Chemists"[22], two from Russell's book[23] (to test separation of variables), and two from Anita Harnadek's Mind Benders[24] (to test hypothetico-deductive reasoning) were selected for the researcher's instrument to measure Piagetian developmental levels.

Instructional Techniques

The fundamental reference used for traditional instruction on formal operational topics was Gagne and Briggs' Principles of

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[21] Deanna Kuhn and Brannock, Joann, "Development of the Isolation of Variables Scheme in Experimental and Natural Experiment Contexts", Developmental Psychology, XIII(1), pp. 9-14, Jan., 1977.

[22] J. Dudley Herron, "Piaget for Chemists", Journal of Chemical Education, LII (March, 1975), pp. 146-8.

[23] John B. Russell, Chemistry: Study Guide for Sienko and Plane/Fifth Edition, (4th ed., New York: McGraw-Hill, 1976), pp. 6, 10-11.

[24] Anita Harnadek, Deductive Thinking Skills-Mind Benders-B2, (Troy, MI: Midwest, 1977). Duplicating Masters, no page.

Instructional Design.[25] The five generally accepted indicators of formal reasoning (proportional, conditional, combinatorial, and probalistic reasoning, and application of universal rules) were used on the CHEM Study textbook to identify formal operational topics.[26] This author used a similar procedure on chemistry textbooks by Smoot[27] and Metcalfe.[28] This was done to assist in identifying formal operational topics to be taught.

In "Piaget in the Classroom", Herron describes specific ways in which the chemistry teacher can differentiate between students who can use formal reasoning and those who cannot. He suggests that even with students capable of formal thought and abstractions, it is important to relate some concepts to concrete examples as often as possible. The chemistry curriculum should be designed so that many concrete experiences and examples are used as the foundation for concepts and activities that require formal reasoning.[29]

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[25] R. M. Gagne and Briggs, L. J., Principles of Instructional Design, (San Francisco, CA: Holt, Reinhart, and Winston, 1974).

[26] Good, Ron, Kromhout, Robert A., and E. K. Mellow. "Piaget's Work and Chemical Education", Journal of Chemical Education, LVI, No. 7 1979, p. 429.

[27] Robert C. Smoot and Price, Jack, Chemistry: A Modern Course, (4th ed., Columbus, Ohio: Merrill, 1975).

[28] H. Clarke Metcalfe and others, Modern Chemistry, 3rd ed.: 5th ed.; New York: Holt, Rinehart, and Winston, 1966, 1974).

[29] J. Dudley Herron, "Piaget in the Classroom", Journal of Chemical Education, LV, March 1978, pp. 165-170.

Lippincott cautioned the chemistry teacher against using Piaget as an excuse to remove the complexity of chemistry content. He instead suggests that there should be an increased awareness that some students have deficiencies in reasoning ability and the challenge to the chemistry teacher is to use the content of chemistry in ways that will facilitate the development of the kind of thinking necessary to understand chemistry.[30]

Both Karplus[31] and Wollman[32] have described concrete and formal reasoning patterns. The "learning cycle" consisting of exploration, concept introduction and concept application explained in Karplus' article was used in the experimental phase of this study. Proportional, combinatorial, probalistic, and conditional reasoning in addition to controlling variables and application of universal rules from Wollman's study were used to instruct students in performing specific logical operational tasks at the formal level.

A further search for Piagetian-based instructional methods led the investigator to Wadsworth's Piaget for the Classroom Teacher. This was the single most valuable source for the treatment employed during the mole concept phase of the investigation.[33] Wadsworth drew

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[30]Walter Lippincott, "Piaget: How Best to Use His Findings, Journal of Chemical Education, LV, 1978, p. 139.

[31]Robert Karplus, "Science Teaching and Development of Reasoning", Journal of Research in Science Teaching, XIV, 1977, pp. 169-175.

[32]Warren T. Wollman, "Controlling Variables: Assessing Levels of Understanding", Science Education, LXI(5), July, 1977, pp. 371-383.

[33]Barry J. Wadsworth, Piaget for the Classroom Teacher, (New York: Longman, 1978), pp. 161-179.

comparisons between mathematics and science concept learning in illustrations between Dienes conceptualizations of the stages of learning mathematics and that of Hawkins' "messing about" in learning science. Both Dienes and Hawkins emphasize the need for structure in their advanced stages.

Piaget for the Classroom Teacher is primarily for elementary school teachers but Wadsworth says:

> Piagetian principles can be applied to all levels of education rather than just the preschool and early primary years, thus allowing for a continuity in rationale for instructional practices throughout the years of schooling. A rationale for traditional classroom practices across grade levels has never been very clear.[34]

Wadsworth's interpretation of Piagetian theory with respect to general teaching considerations, teaching principles, and objectives of education were most valuable for the implementation of the mole concept treatment phase of the research. His comparisons of the similarities and differences between the traditional and Piagetian classroom were most constructive. The 29 assessments and especially the countersuggestions (questions of statements that the teacher can use to determine the resistance of a student's reasoning to change) were also very useful.[35]

In summary, the literature reviewed provided a basis for the development of the researcher's Piagetian developmental level inventory and formulation of instructional procedures which used traditional and Piagetian techniques. The knowledge of the results of other studies led to the formulation and testing of relevant hypotheses in this

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[34] Ibid., p. 121.

[35] Ibid., p. 226, 239-280.

study. Although there were lessons for other science units, this investigator found no chemistry lessons. The factors that are important in designing curricula with strategies that will help students develop the skills inherent in formal operational thought were found.

Chapter 3

RESEARCH DESIGN AND PROCEDURES

An analysis and description of the research design will be presented in this chapter. Methods used to control threats to internal and external validity will be described. A general description of the researcher's Piagetian developmental level classification instrument with scoring and classification procedures will be given. The two types of instruction will be outlined and specific examples described. Finally, the criterion measures will be described with evaluation procedures explained.

Research Design

Description of Subjects

The design was quasi-experimental because existing groups were used. The treatment was not randomized. Since the investigator decided which of the samples received the experimental Piagetian-based instruction and which received the control (traditional) instruction. The research formula was:

$$\begin{array}{l} X_1O_1 \ X_2O_2 \\ \hline C_1O_1 \ C_2O_2 \end{array}$$

The Piagetian-based atomic theory treatment (X_1) was given, achievement was measured by administration of the atomic theory criterion measure (O_1), Piagetian-based mole concept treatment (X_2) was administered and achievement was measured by administration of the mole concept criterion measure (O_2). The nonequivalent control sample received

traditional instruction and achievement was measured by the same criterion measures.

Internal validity threats of history and maturation could not be controlled. These included concurrent enrollment in mathematics and other science courses and the normal maturation effects from September 10, 1979 when the math diagnostic test was administered and the February 19, 1980 testing date for the mole concept treatment.

Regression was controlled by an analysis of covariance. The analysis of covariance allowed for the difference in math scores and the achievement scores on the criterion measures, also calculating the linear regression.[1] The control and experimental samples of the treatment group were nonequivalent in math ability. Even though the math ability, linear regression and the criterion measure scores were not necessarily analytical functions of each other, the analysis of covariance did perform multiple t-tests of least squares linear regression to minimize the sum of the squares of actual data points deviations from the straight line of best fit. This correlation coefficient was calculated from the math and criterion measure variables and the linear equation parameters in the DEC System-20, STP program.[2]

The external validity threat of testing and treatment interaction was minimized by not conducting artificial observations not common to a school setting.[3] If the same treatment were applied to

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[1]Sung C. Choi, Introductory Applied Statistics in Science. (Englewood Cliffs, N. J.: Prentice-Hall, 1978), pp. 216-221.

[2]Digital Equipment Corporation System-20, TOPS-20, Monitor ANOC 1, Western Michigan University.

[3]Donald T. Campbell and Stanley, Julian C. Handbook of Experimental and Quasi-Experimental Designs for Research. (Chicago, IL: Rand McNally College Publishing Company, 1963), reprinted from Handbook of Research on Teaching, p. 41

like groups of students, the reaction to the experimental variable, Piagetian-based instruction, should be typical for a more general universe of interest for which the naturally aggregated exposure group was a biased sample if an analysis of covariance were done for relevant variables. The possibility that the study subjects did not know whether they were in the experimental or control sample would seem to obviate any reactive arrangements threat to external validity.

Piagetian Level Classification

Student responses on the investigator's instrument[4] were scored using the criteria in Table 1

Table 1

Scoring Criteria for Piagetian Level Classification

Tasks	Number of Correct Responses Required: Formal	Transitional	Concrete
Ordering	3-5	1-2	0
Analysis	9-14	4-8	0-3
Inferences	11-23	5-11	0-4
Deductions	4-12	2-3	0-1
Total Number of Responses	29-56	14-28	2-13

[4]Appendix B.

The students were classified on the tasks listed in Table 1 with the number and type of response, not the total number, being used for classification, i.e. students were classified as transitional, for instance, if they responded to one ordering task question correctly and the minimum number of responses on the other three tasks questions as listed in the "transitional" column of the table. The total number of responses could not be less than 14.

Eight of the items allowed free responses with items one and six being concrete. All 78 inventories of the subjects eventually involved in the study were evaluated using the criteria listed in Table 1.

All of the students in the experimental sample during the atomic theory phase of the research were retested on at least one of the three previously cited Piagetian Developmental Level Inventories. Table 2 shows the type of test administered and the number of subjects retested with each one.

Table 2

Instruments Used and Number of Subjects Retested with Each

Test Title	Number of Subjects
An Inventory of Piaget's Developmental Tasks	3
Classroom Test of Formal Operations	3
The Longeot Formal Reasoning Test	10

The disparity in the relative proportion of subjects retested with each of the instruments was due to several factors. An Inventory of Piaget's Developmental Tasks contains 72 items and time to administer it was not always available. The Classroom Test of Formal Operations requires special equipment that was not always available and the method of administration required that the investigator pace the questioning. The Longeot Formal Reasoning Test required the least time to administer and was self-pacing. It was used exclusively before the mole concept instruction when another class became available for the experimental sample. Scoring of these alternative classification instruments was done according to the instructions contained with each of the tests. The assignment to levels by the investigator's instrument and by the other three instruments was compared through use of the chi-square method. The chi-square test was done according to the formula:

$$X^2 = \Sigma \frac{(f_o - f_e)^2}{f_e}$$

with two degrees of freedom and a level of significance of 0.05.

Mathematics Test

The test for the mathematics variable was a locally developed diagnostic test. It contained 80 items with constant numbers of the same type questions selected randomly by each students who took the test so that the total instrument was unique for each subject. The types of questions to be selected and the number of each are identified in Table 3.

Table 3

Question Types-Math Test

Types	No.	Types	No.
Basic Arithmetic Operations	20	Metric to Metric	10
		Metric to English	10
Scientific Notation to Conventional	5	Geometry	10
Conventional Notation to Scientific	5	Algebra I	10
		Algebra II	10

The questions were criterion-referenced to topics mandated as minimal instructional goals or concepts in the eighth grade middle school and high school subjects. Content validity was assumed because the questions were criterion-referenced. Reliability was not done because it was assumed that scores earned reflected the background and retention of concepts for each students tested and the test was diagnostic.

Instructional Techniques

The traditional mode of instruction consisted of (1) lecturing from the textbook,[8] (2) reviewing notes, (3) reading the textbook pages as assigned, (4) working the Group A end of chapter or packet questions, (5) correcting the questions by illustrated discussion

[8] H. Clark Metcalfe and others, Modern Chemistry, (5th ed., New York: Holt, Reinhart, and Winston, 1974), pp. 61-74 for the atomic theory and packet from Robert C. Smoot and Price, Jack, Chemistry: A Modern Course (4th ed.; Columbus, OH: Merrill, 1975), pp. 77-91, 102-3, 104.

in class, and (6) performing a lab, the "Flame Test"[9] in the atomic theory unit and "Stoichiometry: Mass-Mass"[10] in the mole concept unit. Only safety instruction was provided during the treatment for the control sample with no pre-lab or post-lab discussion.

The experimental, Piagetian-based method of instruction consisted of: (1) large-group introduction, (2) small-group activities for laboratory exercises and audiovisual instruction, and (3) self-paced and self-directed individual study. Experimental instruction was based on Smoot and Price's Chemistry: A Modern Course, 4th edition.[11] In atomic theory instruction, additional material developed during the National Science Foundation Workshop on Chemical Bonding at St. Edward's University, Austin, Texas, Summer, 1978 was used. The 1966 3M transparency master series was used to supplement small group instruction. Many teacher-made transparencies illustrating orbital shapes and math techniques were also used for both small group and individual instruction. After explanation and teacher demonstration of a

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[9]H. Clark Metcalfe, Williams, John E. and Castka, Joseph F., Exercises and Experiments in Chemistry, Teachers Edition #48 (3rd. ed., New York: Holt, Reinhart and Winston, 1970), pp. 279-280.

[10]L. Neal Carmichael, Haines, David F. and Smoot, Robert C., consultant, Laboratory Chemistry, annotated teachers edition #8, (3rd. ed.; Columbus, OH: Merrill, 1975), pp. 59-64.

[11]Smoot, op. cit., pp. 194-215.

type reaction and procedure, the students performed Parts A and B of Experiment #13, "Energy Relationships of Metallic Ions."[12] Other visual aids to instruction in atomic theory were a series of six rubber balls of graduated sizes with a quarter section removed to illustrate the "energy levels" and a small steel bearing (to represent the nucleus) was suspended with nylon filament line in the center of the smallest ball. Students constructed s, p, d, and f orbitals of paper and completed the models with them. Balloons with zero, one, and two marbles were used to illustrate the aufbau principle. They were also used to illustrate the Pauli Exclusion Principle. Counter-suggestions were used to allow students to develop concept, rule and problem-solving behaviors. Eleven 55-minute class periods were used to complete the atomic theory instruction for both experimental and control groups.

Before the mole concept treatment was begun, the investigator assumed another Chemistry I class and the experimental sample was expanded to a more appropriate 35 to 38 ratio instead of the 16 to 45 ratio in the atomic theory phase of the research. This was not possible before because of an administrative restriction that all of the investigator's Chemistry I students must be included in the research.

The laboratory exercise used in teaching the mole concept was Experiment #7, "Molar Relationship in a Chemical Reaction."[13] Large group instruction was used to introduce the topic and open-ended discovery-oriented packets of material from Chemistry: A Modern Course[14]

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[12] Carmichael, op. cit., pp. 95-100.

[13] Carmichael, op. cit., pp. 51-58.

[14] Smoot, Loc. cit.

and Solving Problems in Chemistry[15] were issued for use during the period of instruction. The same counter-suggestion technique proposed by Wadsworth[16] was used in the small group/individual activities developed from John B. Russell's book.[17] The following description was the basis for developing counter-weighted models of the nuts described to be weighed on a Mettler top-loading balance with counter-suggestions to elicit a reasonable approximation of the table.

> Mole: Let us consider moles, but before we define one, let us look at some nuts, of the vegetable variety. First we devise an easy way to express the relative weights (actually masses) of these nuts. Our scale of relative weights will be based on the weight of an almond, and the units will be called nutty mass units, abbreviated nmu. Now we define one nmu as a unit of weight equal to exactly one-twelfth the weight of the most common species of almond. Consequently one of these almonds weighs exactly 12 nmu. On this scale of nutty weights an "average" almond (there are several species) weighs 12.01 nmu, an "average" peanut weighs 16.00 nmu, and an "average" walnut weighs 32.06 nmu. (From now on we shall consider only these "average" nuts).
>
> Suppose we are interested in knowing how many almonds must be collected for a pile to weight 12.01 g. We can determine by weighing that the number required is six. Thus, six almonds, each weighing 12.01 nmu, have a total weight of 12.01 g. Now how much will six peanuts weigh? Since each peanut weighs 16.00 nmu, six of them will weigh 16.00 g. (If this is not clear, look at it this way: each peanut weighs roughly sixteen-twelfths as much as six almonds. Sixteen-

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[15] Gary K. Himes, Solving Problems in Chemistry, (3rd ed.; Columbus, OH: Merrill, 1975), pp. 56-80, 113-123.

[16] Barry J. Wadsworth, Piaget for the Classroom Teacher, (New York: Longmans, 1978), pp. 234-280.

[17] John B. Russell, Study Guide for Sienko and Plane Chemistry/ 5th Edition, (4th ed.: New York: McGraw-Hill, 1976), pp. 10-11.

twelfths times twelve equals sixteen.) Following the same line of reasoning, we can see that six walnuts weigh 32.06 g. Now obviously the number six has a special significance: it is the number of nuts that have a total weight (in grams) equal numerically to the weight (in nmu) of one nut. Let us refer to the number six as the Schell number. Now suppose we define a quantity, which we call a freckle, in the following way: one freckle of nuts is 6 nuts, all of one kind. Therefore we can say that one freckle of nuts is the Schell number of nuts and has a weight (in grams) numerically equal to the weight (in nmu) of one nut. These nutty terms and relationships are summarized below:

Nut	Almond	Peanut	Walnut
Weight of one nut	12.01 nmu	16.00 nmu	32.06 nmu
Number of nuts in one freckle	6	6	6
Weight of one freckle	12.01 g	16.00 g	32.06 g

So much for nuts. Turning out attention to atoms and following the same procedure, we consider three different "average" atoms and their weights (masses); an "average" carbon atom (mass-12.01 amu), an "average" oxygen atom (mass=16.00 amu), and an "average" sulfur atom (mass=32.06 amu).

The formal operational students completed the mole task in an average of two point five of the eleven 55-minute instructional periods. Transitional students took an average of five point three class periods. Four of the eight concrete operational students never completed the table. The four who did took from three to seven point five with an average of five point three class periods. The packet was self-paced and self-directed and other types of activities proceeded concurrently.

Criterion Measures

The criterion measure for atomic theory instruction was Tests in Chemistry, 1970, number three which accompanied the text material used

in the treatment process.[18] The criterion measure for the mole concept instruction was applicable portions of "The Mole" from the Merrill Evaluation Program for use with Chemistry: A Modern Course, Fourth Edition, which was the resource text for the learning packet and visuals. It also included material on calories and heats of formation of compounds which were deleted because they were part of a different unit in the primary text. The questions retained were: Part A, 1-10, Part B, 1-7, Part C 1-5, 7 and Part D 1-3, 5, 7, 9, 11 and 13.

Both tests were evaluated on a 100 total point basis. Both tests were judged to have content validity and the reliability was measured by the Kuder- Richardson Formula 21. "Electron Configuration of Atoms" Part I had 33 multiple choice questions with each being scored at one point each. In Part II, questions 34-36, eleven responses were required with each short answer response being scored at three points each. In questions 37-40, 12 responses were required and each was scored at 2.8 points each.

The criterion measure for the mole concept had four parts, each evaluated at 25 points each. On Part A, questions 1-10, each was scored at 2.5 points each. Part B, 7 comprehension level completion questions were scored at 3.6 points each. Part C, questions 1-5 and 7 application level questions were evaluated at 4.2 points each, with some questions having several parts. Part D vocabulary completion questions numbers 1-3, 5, 7, 9, 11, and 13 were evaluated at 3.0 points each.

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[18] H. Clarke Metcalfe, Williams, John E., and Castka, Joseph F., Test 3 "Electron Configuration of Atoms." Tests in Chemistry, 1970, (New York: Holt, Reinhart and Winston, 1970.).

Chapter 4

ANALYSIS OF DATA

The validity of the researcher's Piagetian developmental level inventory was established by administering at least one other accepted test. The results are presented in Table 4 for the atomic theory phase of the experiment.

Table 4

Experimental Sample Piagetian Level
Classification Atomic Theory

Tests	Concrete Level	Transitional Level	Formal Level	X^2
Alternative	3	6	7	1.64
Investigator's	6	5	5	

df = 2 N = 16

The chi square value[1] required for significance is 5.99. Since the calculated value is 1.64, the null hypothesis that there would be no significant difference in Piagetian level classification on different classification instruments is accepted at the 0.05 level of confidence because there is no significant difference between the observed and expected frequencies.

[1] L. R. Gay, Educational Research, (Columbus, OH: Merrill, 1976). Table A. 7. Distribution of chi square, p. 348.

On the mole concept phase of the instruction, when another class of 19 students were added to the experimental sample, the chi square value was 0.74 with 5.99 still being required for significance, the same conclusion was reached. In this case, however, there was a strong possibility of criterion contamination since the experiment had been in progress for seven months.

The reliability of each of the two criterion measures was calculated using the adjusted means and variances from the analysis of covariance computer program.[2] The criterion measure for atomic theory had an $\underline{r} = 0.97$ when calculated by the Kuder-Richardson Formula 21. The criterion measure for the mole concept had an $\underline{r} = 0.67$ when calculated by the same formula. Some of the factors that possibly contributed to this low reliability could have been the diversity of the sections of the test. Parts A and D were knowledge level questions, Part B tested comprehension, and Part C tested analysis. Since the analysis level tested a higher cognitive level than the Piagetian developmental level of some of the students, it seems logical that Sax's comment is applicable: "Items that do not measure the same trait or ability tend to lower the internal consistency of the measurement."[3] The high consistency of the atomic theory of the atomic theory criterion measure would support this explanation also, for two reasons: (1) all of the test questions measured lower cognitive levels, and, (2) the difference

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[2]Digital Equipment Corporation System-20, TOPS-20 Monitor ANOC 1.

[3]Gilbert Sax, Principles of Educational Measurement and Evaluation, (Belmont, CA: Wadsworth, 1974), p. 203.

in the number of test items, 56 on atomic theory and 31 on the mole concept, also tended to decrease reliability. Both criterion measures had content validity.

Table 5 shows the result of the analysis of covariance done between the criterion measure for the mole concept, with breakdown for experimental and control samples, and the covariate math scores. The hypothesis that Piagetian-based instruction was more effective than the traditional method was accepted. The $F = 7.32$ ratio supported that conclusion. The obtained scores computer data is Appendix E.

Table 6 presents the results of the analysis of covariance done between the criterion measure for atomic theory, with breakdown for experimental and control samples, and the covariate math scores. The $F = 17.8$ shows a very low within-group error variance and supports the conclusion that Piagetian based instruction was effective in the atomic theory phase of the experiment.

The hypothesis that no significant difference in achievement scores of concrete operational student would be found in either the control or experimental samples of the treatment group after atomic theory instruction could not be supported, defended, or generalized to the treatment group. The number of concrete operational students in the experimental sample was three and the number in the control sample was 15.

The results presented in Table 7 can be interpreted to show that since $\underline{t} = 2.11$ is greater than 2.08 for 21 degrees of freedom at the 0.05 level of significance, the null hypothesis that there would be no significant difference in the achievement scores of transitional level students during the atomic theory phase of the research in the control

Table 5

Analysis of Covariance
Mole:Math

STP-V4 W.M.U. 10-Jul-80

THERE ARE 3 VARIABLES AND 73 OBSERVATIONS

VAR.	MEANS	STD.DEV.	VARIANCE
MOLE	73.02740	16.71241	279.3048
MATH	61.82192	20.32332	413.0373
GROUP	0.4794521	0.5030349	0.2530441

VAR.	MEDIAN	MODE	MAXIMUM	MINIMUM
MOLE	73.00000	61.00000	98.00000	29.00000
MATH	65.00000	65.00000	100.0000	25.00000
GROUP	0.0000000	0.0000000	1.000000	0.0000000

VAR.	STD ERR OF MEAN	SKEWNESS	COEF. OF VAR.
MOLE	1.956040	-0.4991101	22.88513
MATH	2.378665	0.1281362E-01	32.87397
GROUP	0.5887579E-01	0.8226126E-01	104.9187

STP-V4 W.M.U. 10-Jul-80

***** 1-WAY ANOCOV *****
ANALYSIS ON VARIABLE: MOLE WITH TREATMENTS DETERMINED BY A BREAKDOWN ON VARIABLE: GROUP; COVARIATES USED: MATH

TREAT	SIZE	UNADJUSTED MEAN	ADJUSTED MEAN	COVARIATE MEANS MATH
1	38	68.8	68.2	64.3
2	35	77.7	78.2	59.1
*TOTALS		0.533E+04		0.451E+04
*AVERAGE		73.0		61.8
*BETA WEIGHTS				0.221

1 WAY ANOCOV

SOURCE	SUM OF SQUARES	DF	MEAN SQUARES	F	PROB
BETWEEN ADJUSTED TREATMENTS	1803.225	1	1803.	7.32	.009
ERROR	17242.63	70	246.3		
TOTAL	19045.86	71			

Table 6

Analysis of Covariance Atom:Math

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STP-V4    W.M.U.    8-Jul-80

THERE ARE    3 VARIABLES AND   61 OBSERVATIONS

VAR.          MEANS          STD.DEV.          VARIANCE
ATOM       73.48361          21.21516          450.0831
MATH       58.32787          19.99310          399.7240
GROUP      1.262295          0.4435328         0.1967213

VAR.          MEDIAN            MODE              MAXIMUM          MINIMUM
ATOM       79.00000          94.00000          100.0000          27.00000
MATH       60.00000          65.00000          95.00000          25.00000
GROUP      1.000000          1.000000          2.000000          1.000000

VAR.     STD ERR OF MEAN     SKEWNESS     COEF. OF VAR.
ATOM       2.716323         -0.6197174       28.87060
MATH       2.559954          0.5685457E-01   34.27710
GROUP      0.5678855E-01     1.080766        35.13701


STP-V4    W.M.U.    8-Jul-80

                  ***** 1-WAY ANOCOV *****
ANALYSIS ON VARIABLE: ATOM  WITH TREATMENTS DETERMINED
BY A BREAKDOWN ON VARIABLE: GROUP; COVARIATES USED:
MATH

                UNADJUSTED   ADJUSTED                    COVARIATE MEANS
TREAT SIZE      MEAN         MEAN                 MATH
  1    45       67.9         67.7                 58.8
  2    16       89.3         89.7                 57.1

*TOTALS        0.448E+04                         0.356E+04
*AVERAGE       73.5                              58.3
*BETA WEIGHTS                                    0.358


                        1 WAY ANOCOV

  SOURCE          SUM OF SQUARES     DF     MEAN SQUARES     F          PROB
BETWEEN
ADJUSTED
TREATMENTS        5697.553            1       5698.          17.8       .000
ERROR             18541.43           58        319.7
TOTAL             24238.98           59
```

and experimental samples should be rejected. There is a significant difference in the achievement scores of the transitional level students in the control and experimental samples of the treatment group.[4]

Table 7

t-Test for Independent Samples: Control and Experimental Sample Achievement Scores for Transitional Levels

Sample	t	L.S.	Mean	Standard Deviation
Experimental N = 6	2.11	0.05	89.7	7.00
Control N = 17			76.4	14.70

df = 21 N = 23

The null hypothesis that there would be no significant difference in the achievement of formal operational students in either the control or experimental samples of the treatment group on achievement scores during atomic theory instruction was accepted. The t = 2.12 with 16 degrees of freedom at the 0.01 level of significance was less than the 2.92 required, therefore, there was no significant difference in the achievement scores of the formal operational students in either the control or experimental samples of the treatment group.[5] These data are presented in Table 8.

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[4]L. R. Gay, Student Guide to Educational Research, (Columbus, OH: Merrill, 1976), pp. 148-150.

[5]L. R. Gay, Education Research, (Columbus, OH: Merrill, 1976). Table a.4. Distribution of t., p. 340.

Table 8

t-Test for Independent Samples: Control and Experimental Sample Achievement Scores for Formal Operational Students

Sample	*t*	L. S.	Mean	Standard Deviation
Experimental N = 7	2.12	0.01	96.4	1.9
Control N = 11			84.7	13.6

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter will present a summary of the methods used in conducting the research including the design, development and validation of the classification instrument and analysis techniques. The conclusions reached as a result of this study will be stated. Finally, recommendations supported by the hypotheses tested will be offered.

Summary

This investigation was conducted using a quasi-experimental research design without randomization and nonequivalent math scores. The Piagetian level classification was done with the investigator's instrument which is Appendix B. The students in the experimental sample of the treatment group during the atomic theory phase of instruction were retested with other accepted instruments[1] to establish the validity of the original classifications. When an additional class became available for the experimental sample during the mole

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[1] Center for Research in Thinking and Language, Department of Psychology, Catholic University, An Inventory of Piaget's Developmental Tasks, (Washington, D. C.: Hans Furth, 1970), pp. 1-48. Example of the test is Appendix A; Donald J. Sheehan, trans., "The Effectiveness of Concrete and Formal INstructional Procedure with Concrete and Formal Operational Students", (EdD dissertation, State University of New York at Albany, 1976). Example of the Longeot Test of Formal Reasoning is Appendix D; Anton E. Lawson, "Classroom Test of Formal Operations", Journal of Research in Science Teaching, XV(1), pp. 11-24, 1978. Example of the test and letter of permission for its use are Appendix C.

concept phase of the research, they were all retested with the Longeot Test of Formal Reasoning.[2] The students were instructed by the methods described in Chapter 3 of this thesis. At the conclusion of the instruction in atomic theory, all subjects were tested with Tests in Chemistry, 1970, Number Three which accompanied the text material used in the treatment process.[3] At the conclusion of the instruction on the mole concept, all subjects were tested with applicable portions of "The Mole" from the Merrill Evaluation Program.[4] The validity was judged by content and the reliability by Kuder-Richardson Formula 21. The differences in the Piagetian level classification by the investigator's instrument and other instruments were analyzed by the chi square method. The three hypotheses for the atomic theory phase of instruction concerning Piagetian developmental level and criterion measure achievement scores were done by t-test analysis. Both the atomic theory and mole concept

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[2]Donald J. Sheehan, trans., "The Effectiveness of Concrete and Formal INstructional Procedures with Concrete and Formal Operational Students", (EdD dissertation, State University of New York at Albany, 1975), example of test copy is Appendix D.

[3]H. Clarke Metcalfe, Williams, John E., and Castka, Joseph F., Test 3, "Eelctron Configuration of Atoms," Tests in Chemistry, 1970, (New York: Holt, Rinehart, and Winston, 1970).

[4]Bell and Howell Co., Evaluation Program, Chapter 5 "The Mole" (Columbus, OH: Merrill, 1975), pp. 17-20.

instruction were tested by an analysis of covariance with the math test as the covariate by computer. The analysis of covariance was done to remove any effect that math competencies might have had on the scores obtained on the criterion measures and to measure the effectiveness of the treatments, as determined by the F values for the two hypothesis not related to Piagetian developmental levels.

Conclusions

Although no significant differences were found in classifications by the investigator's instrument and other accepted instruments, the investigator's Piagetian developmental level classification instrument is impractical for use as a measure for a large population. Without extensive instruction in scoring, no other investigator could use the instrument because four Piagetian tasks must first be scored and then the minimum number required for each developmental level must be checked to classify the student. It took three weeks to classify the 78 students who were involved in this research. The fact that it is statistically valid does nothing to improve its practicality.

The analysis of covariance for the math scores, criterion measures, and sample placement increased the power of the study and allowed the ruling out of the math background as a significant factor in the data. It supported the conclusion that Piagetian-based instruction led to higher scores on the criterion measures.

A *t*-test analysis of the difference in achievement scores of the concrete operational students in the control and experimental samples did yield a significant difference. However, the hypothesis that there would be a significant difference in the achievement scores of concrete operational students in the sample which received Piagetian-based

instruction and the sample which received traditional instruction could not be accepted or rejected. There were only three students in the experimental sample compared to 15 in the control sample during the atomic theory phase of the research.

The t-test analysis of the difference in achievement scores of the transitional operational students in the control and experimental samples during the atomic theory phase of the research did yield a significant difference. The hypothesis Piagetian-based instruction for transitional operational students would be more effective was supported.

The t-test analysis of the difference in the achievement scores of formal operational students in the control or experimental samples did not yield a significant difference. It can be concluded that both Piagetian-based or traditional instruction during the atomic theory phase of the research were effective for formal operational students.

Recommendations

Based on the conclusions supported by this study, the following recommendations are made:

Students should be classified by their Piagetian developmental levels early in the school year so that appropriate assistance, counseling and placement can be provided without undue delay. The classification could be done by any acceptable method, either interview or with one of the commerically available instruments. The Longeot Test of Formal Operations[5] is the easiest to score and administer of those

[5] Sheehan, loc. cit.

reviewed in this thesis. Lawson's test is particularly valuable for physics students because of its content.[6]

Since Piagetian-based instruction was effective with both concrete and transitional operational students in this study, and formal operational students were successful with either traditional or Piagetian-based instruction, if more than half the class is not formal operational, it is recommended that abstract topics in chemistry be taught using Piagetian-based methods such as those described for the mole concept and atomic theory in this paper. Wadsworth's book[7] would be a valuable resource as a basis for this at any level or subject.

Throughout the preparation, research and applications of the concepts set forth in this paper, a recurrent theme has been heard from most of the quoted authorities. It has been that efforts to produce some gains in intellectual development are not spectacular and the effort required on the part of both student and teacher is sometimes substantial.

Herron says:

> We have a long way to go before we know how to teach chemistry so that it is understood by all students. Piaget's theory provided a framework for understanding the difficulties that some students have. If it does not eventually show us how to lead students to the promised land of understanding it can at least give comfort to those in the agonies of ignorance, confusion, and frustration.[8]

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[6]Lawson, "Classroom Test. "Loc. cit."

[7]Barry J. Wadsworth, Piaget for the Classroom Teacher, (New York: Longmans, 1978).

[8]J. Dudley Herron, "Piaget in the Classroom,Guidelines for Application," Journal of Chemical Education LV (March, 1978), pp. 169-170.

Since more than 50% of high school chemistry students are not formal operational as documented in most studies, including this one, should any effort be made to change them? If they don't go to college, they need to be able to direct their own learning for the rest of their lives. If they do go to college they will be expected to perform on a formal operational level in science and math particularly.

Students need to be scientifically literate in an increasingly technological society. Since science and technology are by their very nature formal, who will help them acquire formal reasoning processes? Perhaps they will acquire them through development and experience, but it would be a waste of opportunity and even obligation if no effort were ever expended in that endeavor.

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COMPUTER PROGRAMS

Digital Equipment Corporation System-20, TOPS 20 Monitor ANOC 1, Western Michigan University.

APPENDICIES

Appendix A
Title Page
Example of
An Inventory of Piaget's Tasks

Instructions for administering an Inventory of Piaget's Developmental Tasks

The Inventory tasks are derived from Piaget's developmental research. Performance on it should be interpreted in terms of his theory. As a paper-and-pencil task it cannot be appropriately substituted for Piaget's clinical method that uses real objects and a flexible question and answer procedure. The Inventory is intended for adolescents and children who have attained at least some concrete operations. Thus in the majority of cases the useful age range for administering the Inventory extend from age 8 to mid-adolescence.

This Inventory is not a standardized test. It should not be used or interpreted in the same manner as an achievement or an intelligence test. It can, however, be a useful experimental instrument for a preliminary screening or in connection with other diagnostic measures.

The Inventory is composed of 18 problem areas, each consisting of an example and four questions. These problems, named on the inside back cover of the booklet, are presented in an approximate order of difficulty. By design most problems include only a minimum amount of linguistic instructions and can be comprehended on the strength of the pictorial illustrations alone. A possible exception to this are the three final problems: Inclusion, Inference, and Probability.

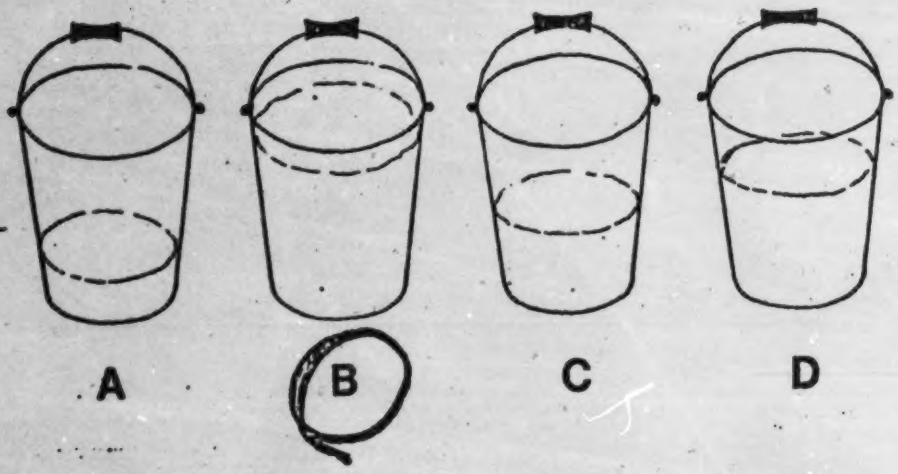
The Inventory is an untimed task with 72 4-choice multiple-choice questions. Answers can either be marked in the booklet or on a separate answer sheet. All problems start with an example to which the answer is given in the booklet; no answer is to be marked for the example on the answer sheet.

Children should be monitored to see that they are marking the answer that corresponds to the number of the question. Each question has only one best answer. Erasures and answer changes are allowed, but only one answer should be marked for each question.

A child should perform the Inventory in numerically consecutive order working at his own speed. There is no scoring penalty for wrong answers. He should be encouraged to complete the Inventory and to speed up if he is spending an excessive amount of time on particular types of items. If a child is very deficient in English reading ability, the teacher can instruct him to omit the last three problems.

example

Which pail has the most water?

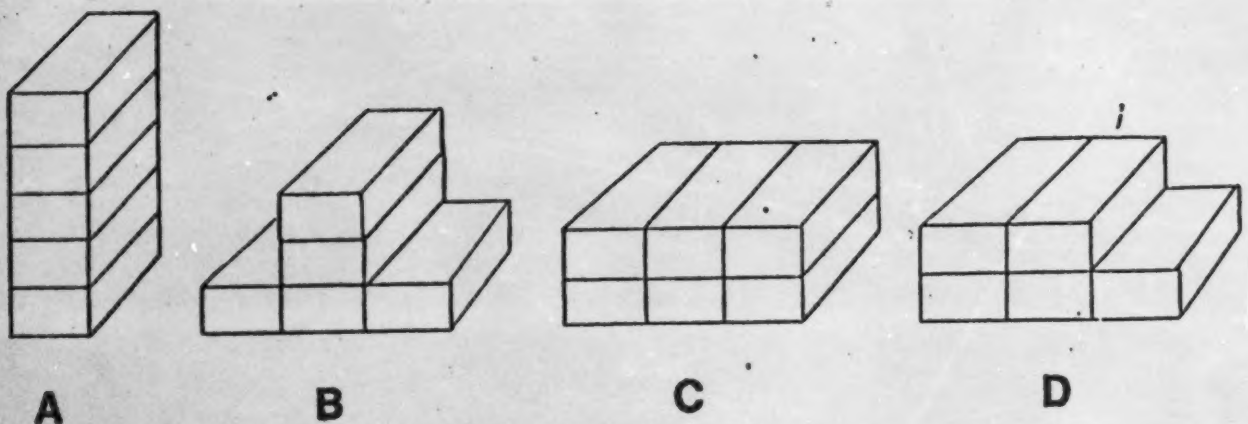


1

Here are some blocks.

The blocks are put into piles.

Which pile has the most blocks?



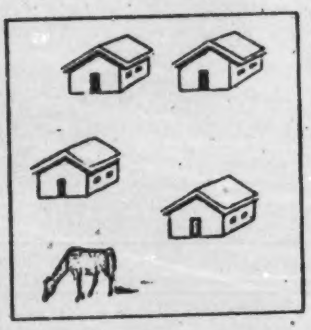
1

2

Here is a hungry horse.

Where does the horse get the most grass to eat?

A



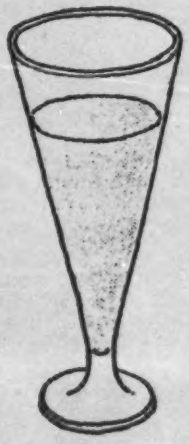
B

C

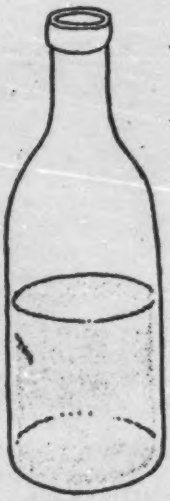
D

3

Which one has the most water?



A



B

C

D

Appendix B
Kletzly's Diagnostic Test, Administration and Scoring Directions

APPENDIX B

NAME KLETZLY'S DIAGNOSTIC TEST DATE _____

This diagnostic test is designed to evaluate your critical thinking ability as an aid to placement in advanced science. It is not the only criterion and will be used to make any necessary counseling suggestions. Since it is diagnostic rather than evaluative, there will be no "passing" or "failing" grades. You are not expected to get all the "right" answers but to provide solutions to most of the questions.

1. Density is defined as the mass (weight) per unit volume. Water has a desnity less than that of sulfuric acid. Which would have the greater density, 100g of water or 100g of sulfuric acid?

   _____

2. "Some of the molecules in solution are blue". One response is "Then all of the molecules are blue". A second response is "Some of the molecules are blue". A third is "None of the molecules is blue". Which is correct?

   _____ (Number)

3. This story is about a young investigator who conditioned a flea to respond to the command "Jump". At every step of the experiment he made careful and detailed notes in his lab book: Procedure: The two hind legs of the flea were grasped securely between thumb and forefinger of the right hand. The flea was held gently in the left hand with the thumb of that hand underneath the abdomen. Both legs were removed simultaneously by means of a sharp pull. The flea was placed on the conditioning table in position 3-y, facing north. The experimenter then said, "jump", in a normal tone.
   Observation: The flea jumped.
   Procedure: Next the experimenter removed the flea's legs in three stages. After the first two pairs of legs were removed it still jumped vigorously when the command jump was given. After the last two legs were removed, however, the flea just remained quivering on the table even when the command "Jump" was repeated.

   OBSERVATION: _____
   _____

   Continue on the back is necessary.

4. Bill is taller than John; Bill is shorter than James; who is the tallest of the three?

   _____

5. If you see several wooden objects burn a logical inference which is a direct extrapolation is that "wood objects burn". Can you make at least 2 inferences which are "twice removed" from that?

   1) _____

   2) _____

6. Classify each of the following statements as a law (L), theory (T) or experimental data (ED). (Pay no attention to whether or not the statements are true.)

____a. Mr. Lavoisler's wine bottle, when dropped down the well, bounded back up.
____b. All wine bottles, except yellow ones, burn brightly when bounced.
____c. The behavior of wine bottles may be explained by assuming that they are very much like puppies.
____d. The behavior of matter undergoing a chemical change may be explained by assuming that it is composed of tiny, indivisible, indestructable particles.
____e. All orange wastebaskets have gentle mufflers.
____f. Any two objects, no matter how far apart, are attracted to each other.

ADVANCED SCIENCE DIAGNOSTIC TEST

7 & 8 The mole concept is very important in understanding certain relationships. The mole is defined: one mole of atoms is 6.02×10^{23} atoms, all of one element. Since you may not be familiar with the mole, let us look at some nuts, of the vegetable variety. We consider three kinds: almonds, peanuts, and walnuts. First, devise an easy way to express the relative weights (actually masses) of these nuts. Our scale of relative weights will be based on the weight of an almond, and the units will be called nutty mass units, abbreviated nmu. Now we define one nmu as a unit of weight equal to exactly one-twelfth the weight of the most common species of almond. Consequently one of these almonds weighs exactly 12 nmu. On this scale of nutty weights and "average" almond (there are several species!) weighs 12.01 nmu, an "average" peanut weighs 16.00 nmu, and an "average" walnut weighs 32.06 nmu. (From now on we shall consider only these "average" nuts.)

Suppose we are interested in knowing how many almonds must be collected for a pile to weigh 12.01 g. We can determine by weighing that the number required is six. Now how much will six peanuts weigh? Walnuts? The number 6 can be referred to as the Schell number. Now suppose we define a quantity, which we call a freckle in the following way: one freckle of nuts is six nuts, all of one kind. Therefore we can say that one freckle of nuts is the Schell number of nuts and has a weight (in grams) numerically equal to the weight (in nmu) of one nut. Summarize these nutty terms and relationships below:
(You should be able to include weights, numbers, freckles, nmu, g and Schell numbers.)

9-10. This is a test of deductive reasoning. (Partial credit will be given, so try!)

A cub reporter interviewed four people. He was very careless, however. Each statement he wrote was half right and half wrong. He went back and interviewed the people again. And again, each statement he wrote was half right and half wrong. From the information below, can you straighten out the mess?

The first names were Jane, Larry, Opal, and Perry. The last names were Irving, King, Mendle, and Nathan. The ages were 32, 38, 45, and 55. The occupations were drafter, pilot, police sargeant, and test car driver.

On the first interview, the wrote these statements, one from each:

1. Jane: "My name is Irving, and I'm 45."
2. King: I'm Perry and I drive test cars."
3. Larry: "I'm a police sargeant and I'm 45."
4. Nathan: "I'm a drafter, and I'm 38."

One the second interview, he wrote these statements, one from each:

5. Mendle: "I'm a pilot, and my name is Larry."
6. Jane: "I'm a pilot, and I'm 45."
7. Opal: "I'm 55 and I drive test cars."
8. Nathan: "I'm 38 and I drive test cars."

ANSWER KEY TO APPENDIX B
ADMINISTRATION AND INTERPRETATION INSTRUCTIONS

Formal operational: Draws inferences, some evidence of deductive reasoning, definite ordering processes.

Transitional: Maximum of two inferences, some evidence of deductive reasoning, so no confusion in ordering age-size comparisons.

Concrete operational: Less then half the items attempted, No inferences, does not understand derived quantities, answered only concrete operational items, no insight evident.

Unclassified: Less than 3 of 10 items correct, literal interpretations, no ordering or analysis present.

Test should be administered with a minimum of 50 minutes available. For those who finish in less than 20 minutes please note. English as a second language, illness or major interruptions should also be noted. Do not administer or continue within 6 months.

1. Sulfuric acid (conservation-concrete)
2. #1 (Inference)
3. The flea could not hear. (Two things dependent on each other, one impossible, other can't be done.) (2 inferences)
4. James (Ordering)
5. They are carbohydrates; carbon objects burn. (2 inferences)
6. a. ED b. L c. T d. T e. L f. T (6 inferences/analysis)

7-8.

Name	nmu	g	freckles	Schell #
Peanuts	16	16	6	1
Almonds	12	12	6	1
Walnuts	32	32	6	1

Partial credit for analysis, ordering inferences=12

9-10.

Jane Mendel	45	Pilot
Opal King	55	Test Driver
Perry Nathan	38	Drafter
Larry Irving	32	Police Sargeant

Partial credit for analysis, deductive reasoning.

Appendix C
Example of
Classroom Test of Formal
Operations and Letter of
Permission for Use

CLASSROOM TEST OF FORMAL OPERATIONS: TESTING AND SCORING PROCEDURES AND ANSWER KEY

ANTON E. LAWSON
SCIENCE EDUCATION
DEPARTMENT OF PHYSICS
ARIZONA STATE UNIVERSITY
TEMPE, ARIZONA 85281

This material is based upon research supported by the National Science Foundation under Grant No. SED74-18950.

Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the National Science Foundation.

Name _____ 59

Birthdate _____
Month Day Year

Sex _____

School _____

Grade _____ Date _____

Directions

For each of the items below a situation will be demonstrated. Each demonstration will lead to a question or questions for which there are a number of possible answers. For each item you are to check the box of the best answer and explain your choice in the space provided.

Example Item: "The Balancing Beam"

- ☐ Mark 3
- ☒ Mark 7
- ☐ Mark 8
- ☐ Mark 10

Please explain your choice.

Equal weights should be placed at equal distances from the center.

Item 1: "Pieces of Clay"

- ☐ The pancake weighs more.
- ☒ The pieces weigh the same.
- ☐ The ball weighs more.

Please explain your choice.

You did not add or take away any clay.

CONTENTS

	Page
I. General Testing Procedures	1
II. Specific Testing Procedures for Each Item	2
III. Scoring Procedures	8
IV. Answer Key	9

Introduction

This fifteen-item test has been developed and validated by Anton Lawson, Journal of Research in Science Teaching, 15(1), 11-24, 1978. Administration of the test requires apparatus like that described in the instructions. Details of the apparatus are not critical, however, because it is never used by the subjects but merely serves to illustrate the questions. Procedures for each test item are described below and are followed immediately by the material to be included in the students' answer booklets. Also given is the answer key. The item titles and spaces for answers and explanations should be assembled into booklets of one or two items per page, but omitting the answer key, of course. "Example" will be done by the class as a whole to introduce the students to the test procedure and the somewhat unusual form of the responses required.

I. GENERAL TESTING PROCEDURES

1. Students should be seated with empty seats between them if possible.

2. Pass out one test booklet to each student.

3. Provide the students with a general introduction to the test by explaining that the test consists of a number of demonstration items that lead to problems. Solution of the problems involves reasoning or problem-solving strategies that are useful in solving problems in a variety of areas. The test will provide information about how familiar you are with these strategies. Explain that some of the items are very easy and some quite difficult. Few students would be expected to get them all correct. Indeed, there may be a number of correct solutions to some of the items.

4. Have the students fill in the information on the top right-hand corner of the test booklet and then read the directions.

5. Explain that they will be progressing through the items as a class. This means that some students may finish some items before others and will have to be patient until all (or nearly all) of the other students have finished before going on to the next item.

6. Do the Example Item, "The Balancing Beam" with the class (see directions below). Have one student volunteer his answer and his explanation. Explain to the class that their explanations need not be lengthy but they should be complete. In this case, a complete explanation would be: "The weights are the same so the lengths should also be the same." Give the students time to write down their explanations and proceed to Item 1.

7. After demonstrating Item 1, give the students time to select an answer and justify their selection. Proceed to Item 2 when all but a few students have completed Item 1. You will have to use your own judgment about pacing as you progress through the rest of the items. You must go quickly enough so that the fast students do not become too impatient but you must go slowly enough so that the slower students have ample opportunity to respond. The entire test normally takes 75 to 90 minutes of class time in one long session or two shorter sessions.

8. It is important that the students understand the situations and the questions as best as they can. For this reason, you may need to repeat or rephrase certain questions and items of information for certain students. This is proper but care must be taken not to provide hints as to the correct solution.

ARIZONA STATE
UNIVERSITY TEMPE, ARIZONA 85281
DEPARTMENT OF PHYSICS

August 31, 1979

Mrs. Nellie E. Kletzly
15906 Bunkeridge Road
Houston, Texas 77053

Dear Mrs. Kletzly,

Enclosed is a copy of my classroom test of formal reasoning which you may use in your study if you wish. Also enclosed is your test with a few comments. In general I found the test extremely ambiguous in terms of what you are asking the student to do. You may wish to compare your test to the Longeot test which is also enclosed. The Longeot test is also a test of logical reasoning.

Best of luck in your research. I hope my comments and the enclosures will be helpful.

Sincerely,

Anton E. Lawson

Anton E. Lawson
Associate Professor
Science Education

AEL:eml

Enclosures

Appendix D
Example of
The Longeot Test of
Formal Reasoning

F.O.L.P.
F.O.P.
F.C.O.

PARTS III & IV

Copyright - 1971
D. J. Sheehan

14. Problem:

Three groups of children at a lake are going to go swimming, accompanied and watched by lifeguards.

- The first group consists of 14 persons: 12 children and 2 lifeguards.

- The second group consists of 8 persons: 7 children and 1 lifeguard.

- The third group consists of 24 persons: 21 children and 3 lifeguards.

Which group of the three is the best watched?

A--The first group is the best watched because this one has the most lifeguards in relation to the number of children.

B--The second group is the best watched because this one has the least number of children to be watched.

C--The third group is the best watched because this one has the most lifeguards to watch the children.

D--The three groups are watched equally well for in the first case there are 2 lifeguards out of 14 persons, being 1 lifeguard for every 7 persons, in the second case, there is 1 lifeguard for 7 children and in the third case there are three lifeguards for 21 children, being 1 lifeguard for every 7 children.

PART III

Are You a Good Detective?

You are going to do some small problems in which the statements are a little involved. You will find yourself in the situation of a detective who receives clues during his investigation and is seeking to discover the truth by his reasoning and deduction. The detective makes some assumptions and looks for proof with what he is told and what he observes.

Now, read the three sentences of the statement which follows and by thinking carefully, try to find out if the conclusions which are placed below the statement are true or false.

Example: Statement:

- If Paul lied, then Peter killed John.
- If the weapon was a pistol, then Paul lied.
- But today, it was learned that the weapon was indeed a pistol.

Conclusions:

A - Paul lied.
B - Paul didn't lie.
C - Peter killed John.
D - Peter didn't kill John.
E - One cannot know it.

You are asked to choose the conclusions of the investigation which are correct among these 5 conclusions.

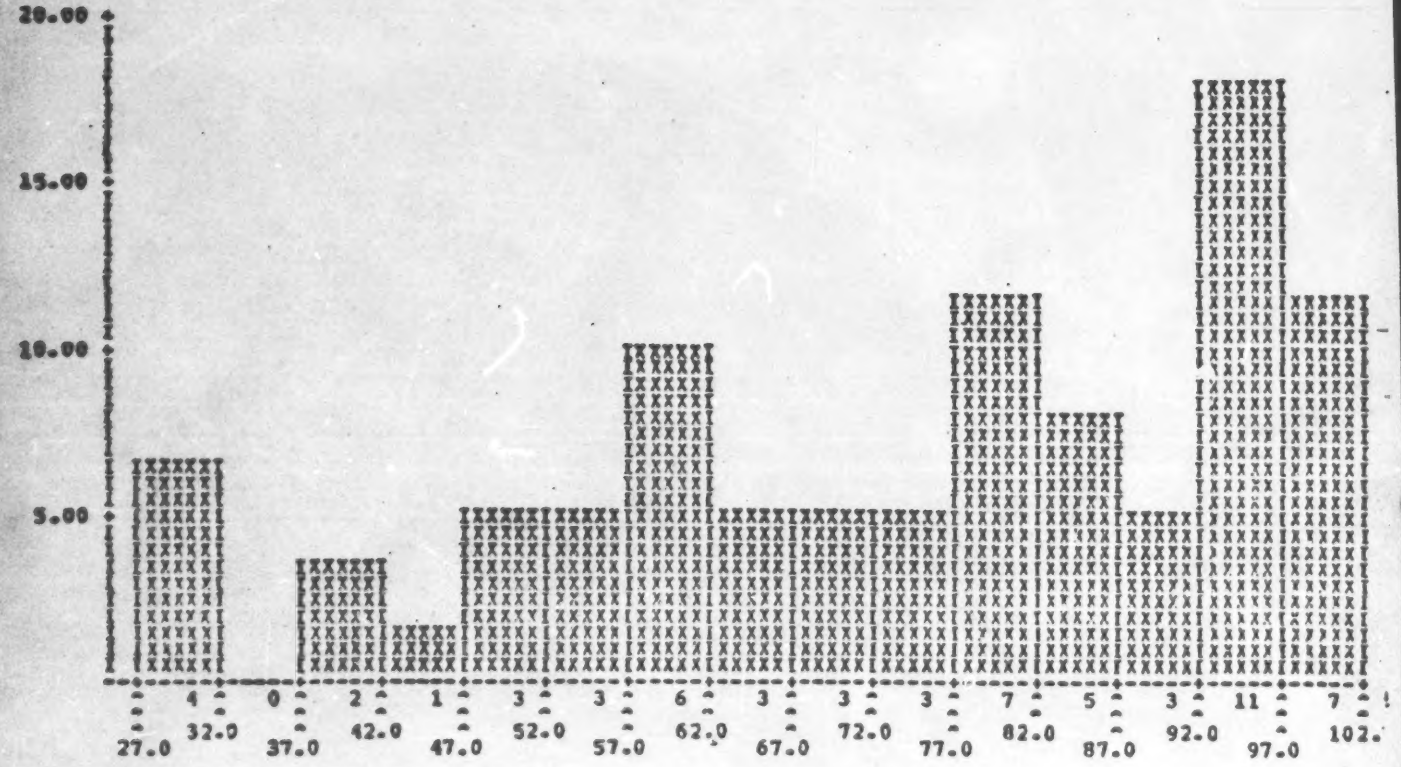
With the given statement of the problem, you first try to find whether Paul lied or not, and then you can discover whether Peter killed John or if Peter didn't kill John.

Place an "X" in the square below the letter C and in the square below the letter A, for these are the two correct conclusions of the investigation.

Do the other problems, and each time try to choose the correct conclusions. You see that now there is more than one correct answer for each of the problems.

DO NOT TURN THE PAGE UNTIL THE SIGNAL IS GIVEN.

Appendix E
Computer Data



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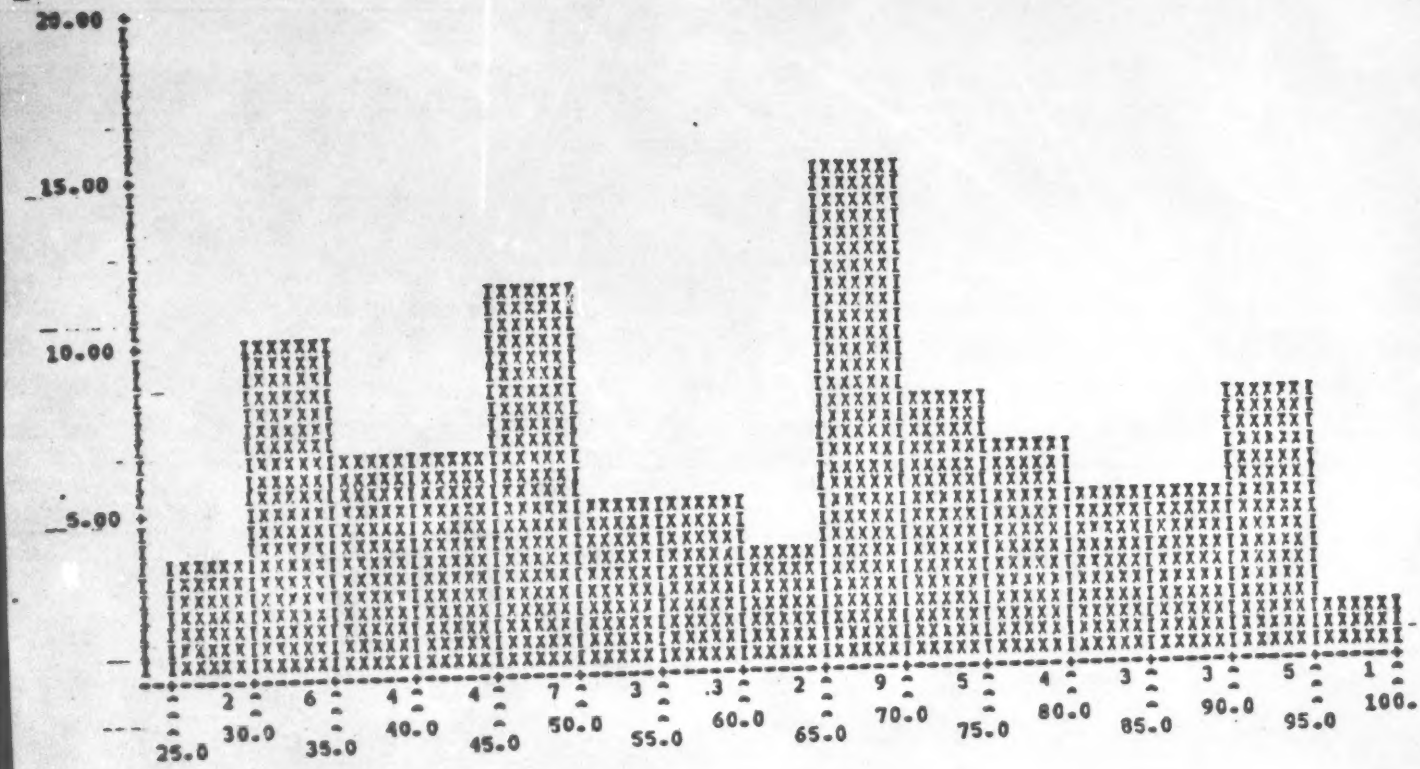
STP - V4 W.M.U. 8-Jul-80



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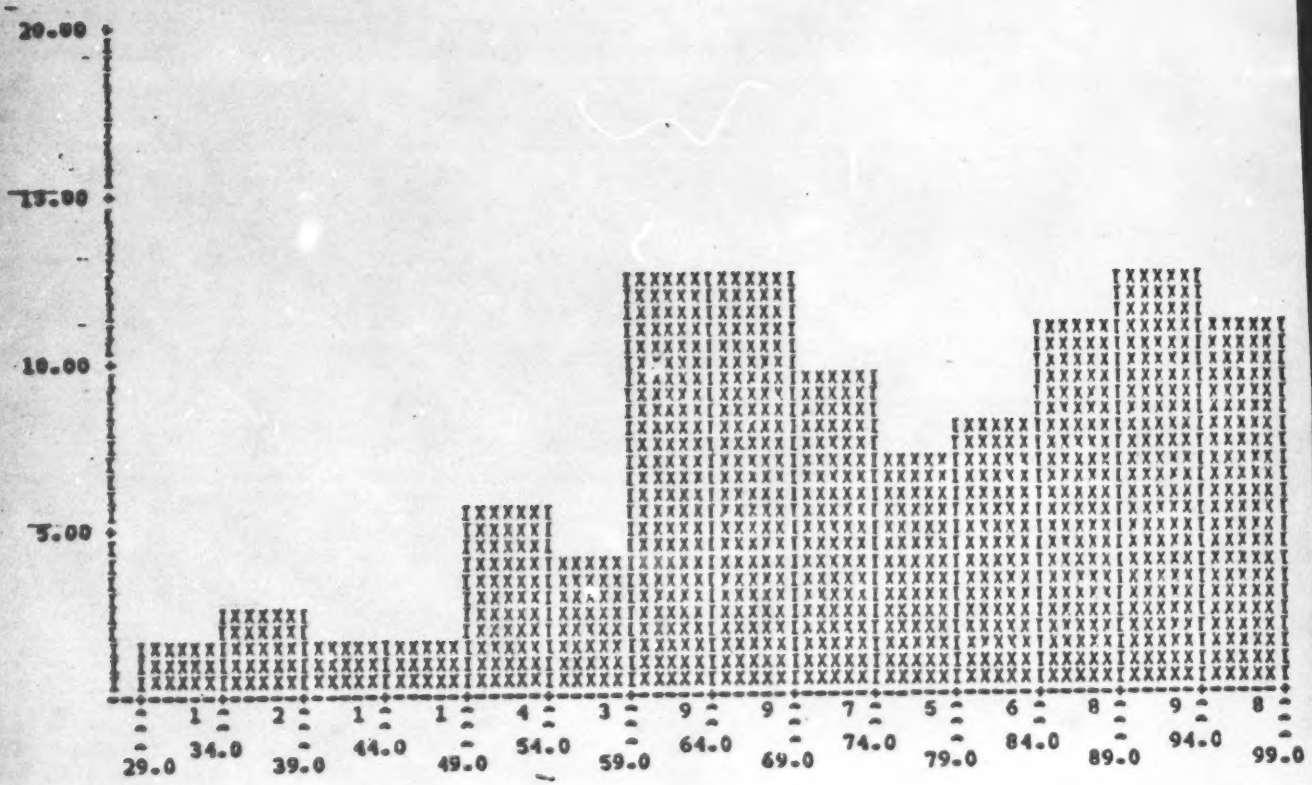

HISTOGRAM FOR VARIABLE: MOLE

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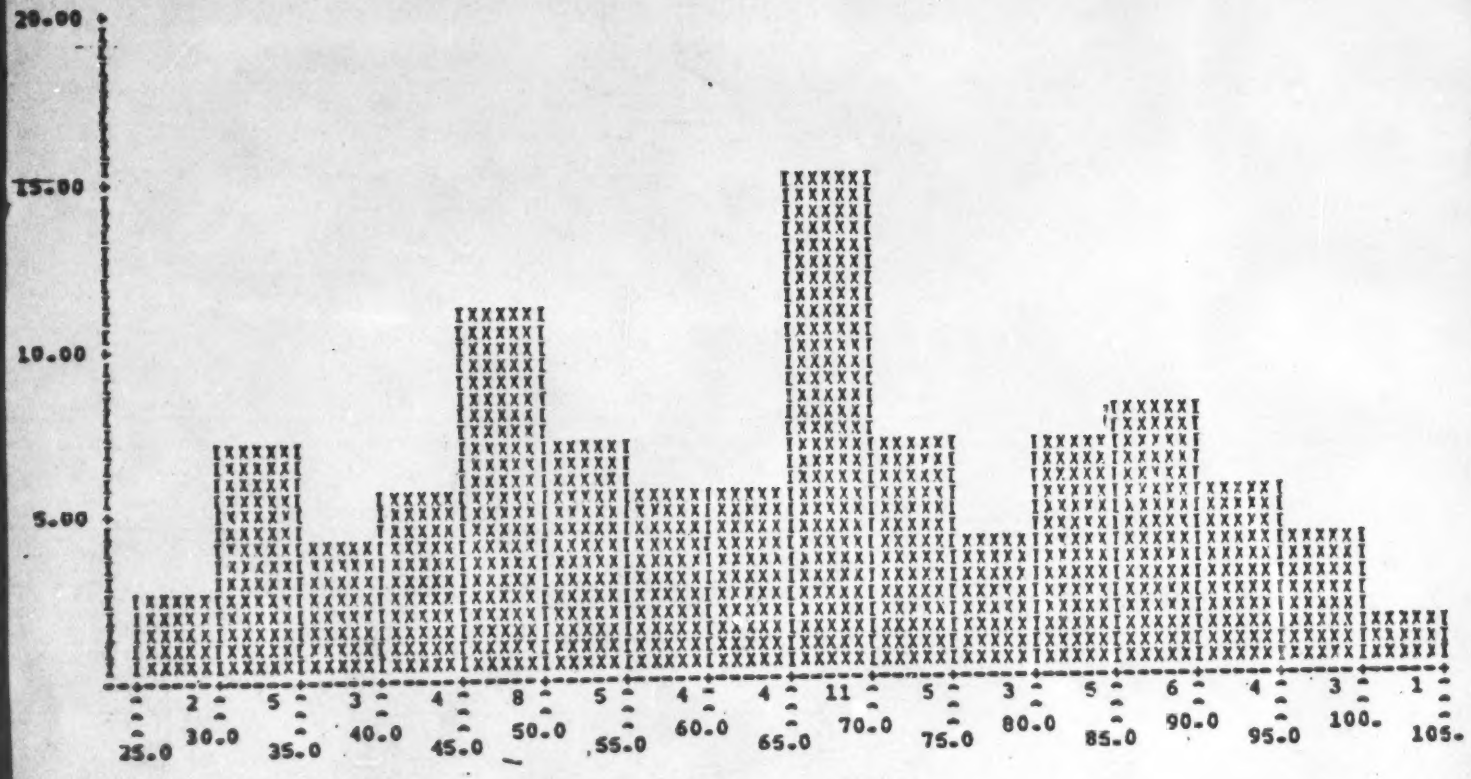

HISTOGRAM FOR VARIABLE: MATH

STP - V4 W.M.U. 10-Jul-80

STP - V5 WMU

VAR

OBS	MOLE	MATH	GROUP
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2	63.00000	60.00000	0.0000000
3	90.00000	65.00000	0.0000000
4	45.00000	50.00000	0.0000000
5	51.00000	30.00000	0.0000000
6	36.00000	80.00000	0.0000000
7	83.00000	80.00000	0.0000000
8	68.00000	25.00000	0.0000000
9	85.00000	87.00000	0.0000000
10	61.00000	52.00000	0.0000000
11	50.00000	83.00000	0.0000000
12	71.00000	47.00000	0.0000000
13	40.00000	67.00000	0.0000000
14	78.00000	83.00000	0.0000000
15	63.00000	40.00000	0.0000000
16	61.00000	30.00000	0.0000000
17	75.00000	65.00000	0.0000000
18	67.00000	45.00000	0.0000000
19	64.00000	50.00000	0.0000000
20	70.00000	45.00000	0.0000000
21	66.00000	55.00000	0.0000000
22	61.00000	30.00000	0.0000000
23	50.00000	70.00000	0.0000000
24	77.00000	40.00000	0.0000000
25	77.00000	65.00000	0.0000000
26	93.00000	93.00000	0.0000000

STP-V5 WHU

OBS	MOLE	VAR MATH	GROUP
27	84.00000	97.00000	0.0000000
28	89.00000	97.00000	0.0000000
29	61.00000	87.00000	0.0000000
30	65.00000	87.00000	0.0000000
31	85.00000	67.00000	0.0000000
32	54.00000	70.00000	0.0000000
33	88.00000	83.00000	0.0000000
34	92.00000	70.00000	0.0000000
35	73.00000	53.00000	0.0000000
36	98.00000	100.0000	0.0000000
37	86.00000	60.00000	0.0000000
38	64.00000	60.00000	0.0000000
39	66.00000	35.00000	1.000000
40	83.00000	30.00000	1.000000
41	56.00000	35.00000	1.000000
42	69.00000	75.00000	1.000000
43	72.00000	45.00000	1.000000
44	68.00000	25.00000	1.000000
45	54.00000	40.00000	1.000000
46	63.00000	60.00000	1.000000
47	80.00000	45.00000	1.000000
48	94.00000	65.00000	1.000000
49	91.00000	55.00000	1.000000
50	97.00000	45.00000	1.000000
51	82.00000	35.00000	1.000000
52	94.00000	65.00000	1.000000

Table 6

Analysis of Covariance
Atom:Math

SEP-75 WHO

VAR

OBS	MOLE	MATH	GROUP
53	93.00000	85.00000	1.000000
54	51.00000	65.00000	1.000000
55	95.00000	65.00000	1.000000
56	64.00000	40.00000	1.000000
57	89.00000	70.00000	1.000000
58	61.00000	55.00000	1.000000
59	89.00000	65.00000	1.000000
60	86.00000	45.00000	1.000000
61	89.00000	95.00000	1.000000
62	81.00000	90.00000	1.000000
63	95.00000	90.00000	1.000000
64	87.00000	85.00000	1.000000
65	86.00000	30.00000	1.000000
66	35.00000	70.00000	1.000000
67	79.00000	50.00000	1.000000
68	95.00000	65.00000	1.000000
69	71.00000	55.00000	1.000000
70	61.00000	75.00000	1.000000
71	97.00000	85.00000	1.000000
72	76.00000	45.00000	1.000000
73	69.00000	90.00000	1.000000

VITA

Nellie E. Kletzly nee Sparks is the eldest of four children born to Troy W. and Gladys Sparks. She was born July 27, 1938 in Pikeville, Kentucky. She attended Pikeville Public Schools from 1942 until 1956, graduating by general educational development (GED). She enrolled at Mary Hardin-Baylor College (now University), at Belton, Texas, in 1965 and received the Bachelor of Science degree from that institution on August 23, 1968, with majors in biology and chemistry and a minor in secondary education. She has done past baccalaureate and graduate studies at the University of Maryland European Division, North Texas State University, University of Houston, and St. Edward's University at Austin, Texas before enrolling in June, 1979 at Sam Houston State University, Huntsville, Texas and graduating in August, 1980 with the Master of Arts degree in secondary education with a minor in chemistry.

She taught eighth grade life science at Galveston in 1968, substituted at Nurnberg American High School and taught preparation for the GED test at William O. Darby Kaserne, Nurnberg, West Germany from 1969-1971 and substituted at the Temple, Belton, and Killeen, Texas public schools from 1972-1973. From 1975 until 1978 she taught biology, ecology, technical chemistry and anatomy and physiology at Evan E. Worthing High School, Houston, Texas, transferring for the 1978-1979 school year to the Jesse H. Jones High School Vanguard Program where she taught science fiction, Chemistry I and Chemistry II. During the 1979-1980 school year she taught Chemistry I and II at Humble High School, Humble, Texas.

In addition to teaching she has served as an oboeist in the Women's Air Force Band in 1956-7 and as a Medical Administration Specialist/Corpsman at Wilford Hall Air Force Hospital, Lackland Air

Force Base Hospital, San Antonio, Texas from 1957-1959. She was a public and high school library aide from 1952-1956 in Pikeville, Ky.; medical library administration specialist, Lackland Air Force Base, 1957-1959; Iran-American Society Library aide, 1959; Ft. Hood Post Library part-time temporary reference librarian, 1963-1965. In 1960, she was an assistant in the security division of J. A. Jones Construction Company, Teheran, Iran. In 1969, she was a clinical laboratory technician at John Sealy Hospital, University of Texas Medical Branch, Galveston, Texas and from 1974-1975, a medical laboratory technologist at The Methodist Hospital, Houston, Texas. She was a chemical assayist for Metabolic, Inc., a private manufacturer of laboratory control chemicals in 1973.

Her professional memberships include local, state and national teacher organizations, former member of the Texas Academy of Science, Texas Classroom Teachers Association, and Texas Academy of Science Collegiate Academy, serving as North East Texas Director and editor of its journal from 1966-67. She is also a current member of the Metropolitan Houston Chemistry Teachers Association, Metropolitan Area Teachers of Science, Science Teachers Association of Texas, and associate member of the American Chemical Society Gulf Coast Section. She is a certified specialist in Clinical Chemistry with the American Society of Clinical Pathology and a member of that organization also. She has been a parlimantarian and constitution writer for three parent-teacher organizations and two social organizations and a catechism teacher and sponsor for the Catholic Youth Organization in three locations.

She married then SSG John F. Kletzly, Jr. in 1959 and accompanied him on three overseas tours of duty to the American Embassy, Teheran, Iran, 1959-60; Herzogenaurach, West Germany, 1960-63; 1969-1972. They have one son, born at Nurnberg Army Hospital and presently a sophomore petroleum engineering major at Texas A & M University, College Station, Texas. Mr. Kletzly retired from active duty in 1973 and is currently a letter carrier at the Westfield Substation of the Houston Post Office. They currently reside in Spring, Texas.